NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

THEMATIC MAPPER RESEARCH IN THE EARTH SCIENCES

Tectonic Evaluation of the Nubian Shield of Northeastern Sudan/Southeastern Egypt Using Thematic Mapper Imagery

INTERIM REPORT

BECHTEL NATIONAL, INC.

February, 1986

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

THEMATIC MAPPER RESEARCH IN THE EARTH SCIENCES

Tectonic Evaluation of the Nubian Shield of Northeastern Sudan/Southeastern Egypt Using Thematic Mapper Imagery

INTERIM REPORT

BECHTEL NATIONAL, INC.

February, 1986

1.0 Summary

The tectonic evaluation of the Nubian Shield using Thematic Mapper (TM) imagery is progressing well and shows great promise. The TM tapes for the six Landsat 5 scenes covering the northern portion of the Red Sea hills required to perform Bechtel's contract were received during the period from September to December, 1985. Preliminary maps and interpretations have been made for most of the area. Although it is premature to present much in the way of interpretation at this time, it is apparent that faulting and shearing associated with the major suture zones such as the Sol Hamed are clearly visible and that considerable detail can be seen. Splays, branches and/or smaller suture zones are also in evidence.

An entire quadrant of scene 173,45 was examined in detail using all seven bands, and every band combination was evaluated to best display the geology. A comparison was done with color ratio combinations and color combinations of the eigen vector bands to verify if band combinations of 7-red, 4-green, and 2-blue were indeed superior. There is no single optimum enhancement which provides the greatest detail for every image and no single combination of spectral bands for all cases, athough bands 7, 4, and 2 do provide the best overall display. Special conditions, however, require different combinations and techniques to obtain maximum information. The color combination of the eigen vector bands proved useful in distinguishing fine detailed features.

The Thematic Mapper images are of outstanding quality and have a versatility that allows the investigator the opportunity to check many parameters. The 30 meter pixel size and the large electromagnetic spectrum spread of the TM allows rock units to be differentiated and traced and the structural fabric to be seen in good detail. Although we are still in the preliminary mapping and interpretation phase, it is already apparent that the amount of information available is truly impressive.

The preliminary map and interpretation will be completed in a few months. We plan to follow this effort by reconnaissance mapping of selected areas as a field check on structures and rock types. The completion of the final map and report can then be accomplished. Work under the contract is progressing satisfactorily. The project goals and deadlines defined in the contract are expected to be met.

2.0 Background Data

National Aeronautics and Space Administration contract NASS-28757 was awarded to Bechtel National, Inc. with an Effective Date of August 19, 1985 and received on September 4, 1985. The contract is for a Landsat Thematic Mapper (TM) Data Investigation entitled "Tectonic Evaluation of the Nubian Shield of Northeastern Sudan Using Thematic Mapper Imagery". The area to be evaluated is located in northeastern Sudan and southeastern Egypt as shown on Figure 1. The Landsat 5 tapes to be studied under this contract were provided by NASA.

The plan for accomplishing this evaluation was subdivided into the five following phases: (1) literature acquisition and review; (2) Thematic Mapper data acquisition and processing; (3) map preparation and tectonic interpretation; (4) field reconnaissance, and (5) report generation.

The TM imagery provided by NASA consists of six Landsat 5 digitized tapes recording seven spectral bands of the following scenes:

Path	Row
171	46
172	45
172	46
173	44
173	45
173	46

The last of these scenes was received in December.

These Landsat tapes were processed on Bechtel's remote sensing equipment and are being analyzed to develop a Tectonic Map of the area. At the present time we are in Phase 3 (map preparation and tectonic interpretations); some Phase 2 work is still to be finalized. Figure 1 shows the location of the scenes being analyzed. The hachered area indicates the location of the illustrative quadrant utilized for Figures 2 and 3 of this report.

3.0 Work Accomplished

3.1 Literature Acquisition and Review

The acquisition and review of pertinent literature concerning the geology and tectonic history of the project area is largely completed, but review will continue as needed until the last report is finalized and ready for publishing. Many excellent papers have been (and are still being) written on the Precambrian Nubian-Arabian shield complexes and the accretions to them. References reviewed to date are listed in Section 5. The list will be augmented as new published information becomes available.

3.2 Landsat TM Imagery

The acquisition of the TM tapes was completed on 13 December; however, processing was initiated as each of the tapes arrived. The entire Q2 of Scene 173,45 was examined using all seven bands. Although a variety of features and colors were seen, a statistical study showed that the data in the spectral bands was highly correlated. Due to the high correlation, every band combination was evaluated to best display the Nubian Shield geology. A combination of bands 7, 4, and 2 was chosen for primary interpretation with the remaining bands to be utilized as needed for special conditions or supplementary verifications. To verify that the band combination of 7(-red), 4(-green), and 2(-blue) was best for

enhancement of major lithologies and structural features, a comparison was done with color ratio combinations and color combinations of the eigen vector bands. All color ratio combinations were considered inferior to the 7, 4, 2 combination. The color combination of the eigen vector bands did not provide a useful image for overall enhancement, but is useful to distinguish fine detailed features.

Having chosen a contrast stretch of spectral bands 7, 4, and 2, the TM scenes were divided into quadrants as the basic size for making photographic copies. This produced 18 by 18-inch working prints at a scale of 1:200,000 (1 cm = 2.0 km). These prints are overlain by a clear acetate plastic sheet and the geologic interpretation is plotted on the acetate.. The interpretation of the geologic features is made from the image on the screen, utilizing enhancement and contrast-stretch techniques of the scene being studied. Plotting and preliminary analyses of the geologic features on most of the quadrants has already been completed.

3.3 Analysis

Quadrangle Q3 of scene 173,44 was chosen to serve as an illustrative example because of its location as well as the diversity of geologic features it displays. It is entirely within the Egyptian portion of the Red Sea hills thus may offer a better chance of access for field verification than would a similar quadrant in Sudan.

Determination of rock types represented on the imagery presently depends primarily on the identifications and locations of rock types shown in the literature. Based on the descriptions in the literature of distinctive features that can be identified on the imagery and on the reflective characteristics of these features as recorded by the TM sensors, the identified unit is traced to its geologic boundary. Units that appear to be similar and have the same characteristics are considered to be the same unit.

Many variations of rock type and condition occur in the Q3 area. For example, one of the major metasedimentary units (BA) locally grades into older granitics as well as into the older sediment volcanic series and displays characteristics common to both. Most of the Precambrian sedimentary units are reported to be volcaniclastics with some interbedded lava flows and dikes, limestones, cherts, turbidites, and other marine rock types.

Dikes of many orientations can be seen in Figure 2 but the most prevalent direction is northeast, parallel to the grain of the formations in this figure. One of the areas showing a concentration of dikes is the northeast portion of Figure 2 where the dark coloration of the dikes makes them stand out against the lighter-colored granitics and metamorphics. Dikes up to 20 kilometers long can be seen and many are 5 to 10 kilometers long. Several generations of dikes can be observed based on their cross-cutting relationships.

At times it is difficult to distinguish between dikes parallel to the relic bedding in the metasediments, and resistant beds that stand out in relief. On the imagery both are visible in rock exposures, project through the areas covered by shallow sand, and are often of similar mafic composition. Generally the dikes can be distinguished by minor cross-cutting of bedding, or by having spectral characteristics similar to other well defined dikes in the area.

One of the large fault/suture zones so visible on the TM imagery of Q3, enters from the southcentral portion of the image, turns westerly and leaves the scene at the middle portion of the western edge. It appears to be a branch of the much larger north-south trending Sol Hamed suture zone which extends through the eastern quadrants of Scene 173,45 and splays in several directions. Figure 3 shows our preliminary interpretation of scene 173,44 Q3, a photograph of which is shown as Figure 2.

The sutures (zones marking the boundaries between accretionary terranes) as seen in the imagery are characterized by bands of sheared rock many kilometers wide with numerous contorted and strung-out units within a melange. Lithologies and textures change rapidly, particularly normal to the strike of the suture. Within the suture zone melange, many of these units occur as exotic blocks juxtaposed with older igneous intrusions which have been distorted in outline. Undistorted younger intrusions, identified by their sharply circular outlines, protrude indiscriminantly through the sutures, older granitics, and metasediments throughout the study area.

Major structural units such as sutures, large faults, and igneous intrusions are readily visible on the photographic copy of a scene, but similar appearing geologic units can best be distinguished on the screen where the full suite of electromagnetic bands available to the TM can be called up. This can be well illustrated by comparing the "black" areas in lower portions of Figure 2, all of which look similar in this photo, with the preliminary interpretation made in Figure 3. The large crescent shaped area in the lower left is composed of ultramafic material (probably serpentine); the large irregularly shaped patch to the right of center is primarily one of the mafic volcanic units within the metasediments. In Figure 2 the "black" areas look virtually the same, but manipulated on the CRT screen, distinct reflective differences are apparent.

A minor feature noted in the southeast quadrant of Q3, scene 173,44, has been a source of considerable speculation during the preliminary work. The feature is shown at an enlarged scale in Figure 4. As simply one more circular feature with an elevated rim in an area noted for circular intrusions with ring dikes, its unique qualities were initially overlooked and it was assumed to be just another intrusion. However, due to the resolving power inherent in the TM imagery system, it was possible to greatly enlarge this feature and examine it in more detail; it is now identified as a probable astrobleme (impact crater). This astrobleme(?) is of sufficiently recent origin that its crater rim, composed of debris, is still relatively intact. Because of its central

cone, consideration was given to its being a caldera with a resurgent cone. Lack of apparent lava flows or volcanic ejecta which should be noticeable near a caldera as young as this, seems to rule out that possibility.

It appears that much can be learned about the source of the sand in the imagery from its apparent color even though these colors are false. In Figure 2 the white sand seems to relate to a granitic source while the pink to purple sand occurs primarily over the metasediments. The yellow sand extending southward from the top center of the image represents the front of a large mobile sand field which covers much of 173,44 Q2 and is now penetrating Q3. Note the dune field near the top of the figure just to the right of center. No attempt was made to show the locations of surficial deposits on Figure 3 at this time.

4.0 Work Planned

During the next 6 month period most of the remainder of the work needed to complete the Final Report will be accomplished. Included will be:

- Completion of the preliminary Tectonic Map from the TM imagery
- Completion of the preliminary map interpretation.
- Discussion of preliminary mapping and interpretation with consultants and other workers in imagery interpretation.
- Field verification of as many of the stratigraphic and structural units shown as possible within budget limits.
- Based on the results of the field work the imagery will be reviewed and the map and preliminary interpretations revised if needed.
- Start on Final Report draft.
- Prepare 2nd Semi Annual Report for distribution.

The next 6 months will be very active ones and while the items shown above are placed in rough chronological order there will obviously be

overlap and even some deletion and additions. Much depends on if the proposed field check proves infeasible. At the present time we have more information than we have had time to assimilate. Before the next Semi-Annual Report is due we hope to have this data largely evaluated and be working it into the Final Report.

5.0 BIBLIOGRAPHY

Abdel-Khalek, M.L., 1979. Tectonic evolution of the basement rocks in the southern and central eastern deserts of Egypt: Precambrian Res., v. 6, no. 1, p. A2-A3.

Ahmed, F., 1982. Implications of the Precambrian lineaments on the Red Sea Tectonics based on Landsat study of northeast Sudan: Global Tect. and Metallogeny, v. 1, no. 4, p. 326-335.

Ahmed Ibrahim, F., 1983. Sudan's mineral deposits: Mining Mag, v. 148, no. 1, p. 31-35.

Almond, D.C., Ahmed, F. and Dawoud, A.S., 1982. Tectonic, metamorphic and magmatic styles in the northern Red Sea Hills of Sudan: Precambrian Res., v. 16, no. 4, p. A4-A5.

Al-Shanti, A.M.S. and Roobol, M.J., 1979. Some thoughts on metallogenesis and evolution of the Arabian-Nubian Shield: I.A.G. Bull. no. 3, v. 1, p. 87-96.

Bentor, V.K., 1985. The crustal evolution of the Arabo-Nubian Massif with special reference to the Sinai Peninsula: Precambrian Res., v. 28, p. 1-74.

Camp, V.E., 1984. Island arcs and their role in the evolution of the western Arabian Shield: Geol. Soc. Am. Bull., v. 95, no. 8, p. 913-921.

Conway, C.M., Elliott, J.E. and Stoesser, D., 1979. Mineral belt studies: U.S. Geol. Surv., Prof. Paper 1150, 332 p.

Dawoud, A.S., 1982. Mozambiquan and Pan-African events in part of the Nubian Shield, North Nile Province, Sudan: Univ. Khartoum, Khartoum, SDN.

Duyverman, H.J. and others, 1982. Late Precambrian evolution of Afro-Arabian crust from ocean arc to craton, discussion and reply: Geol. Surv. Am. Bull., no. 93, no. 2, p. 174-178.

El Shazly, E.M., El Sokkay, A.A. and Aly, M.M., 1982. Development of granitics and associated granitoids in Egypt according to alternative orogenic and plate tectonic models: Precambrian Res., v. 16, no. 4, p. A56.

Embleton, J.C.B. and others, 1982. A new approach to the stratigraphy and tectonic evolution of the Red Sea Hills, Sudan: Precambrian Research, v. 16, no. 4, p. A19.

Fitches, W.R. and others, 1983. The late Proterozoic ophiolite of Sol Hamed, NE Sudan: Precambrian Res. v. 19, p. 385-411.

Fleck, R.J. and others, 1981. Geochronology and isotope studies: U.S. Geol. Surv., Prof. Paper 1275, 291. p.

Davies, F.B., 1984. Strain analysis of wrench faults and collision tectonics of the Arabian-Nubian Shield: Jour. Geol., v. 92, no. 1, p. 37-53.

Greenberg, J.K., 1981. Characteristics and origin of Egyptian younger granites: Summary: Geol. Soc. of Am. Bull., Part 1, v. 92, p. 224-232.

Greiling, R., Kroener, A. and El Ramly, M.F., 1984, Structural interference patterns and their origin in the Pan-African basement of the southeastern desert of Egypt, in Kroener, A., Greiling, R., editors, Precambrian tectonics illustrated: Federal Republic of Germany, E. Schweizerbartlsche Verlagsbuchhandl, p. 401-412.

Harns, N.B., Hawkesworth, C.J. and Ries, A.C., 1984. Crustal evolution in Northeast and East Africa from moded Nd ages: Nature, v. 309, p. 773-776.

Hepworth, J.V., 1973. Does the Mozambique Belt occur in Saudi Arabia?: Precambrian Res., v. 6, no. 1, p. A26.

Hepworth, J.V., 1979. Does the Mozambique Orogenic Belt continue into Saudi Arabia?: I.A.G. Bull. no. 3, v. 1, p. 39-51.

Kazmin, V., 1978. Geology of the Ethiopian basement and possible relation between the Mozambique and Red Sea belts: Egypt. Jour. Geol., v. 22, no. 1.

Kroner, A., 1985. Ophiolites and the evolution of tectonic boundaries in the late Proterozoic Arabian-Nubián Shield of Northeast Africa and Arabia: Precambrian Res., v. 27, p. 277-300.

Kroener, A. and Jahn, B.M., 1985. Precambrian crustal evolution: Precambrian Res., v. 27, p. 277-300.

Moore, J.M., 1982. Structure, stratigraphy, and mineralization in the southern Arabian Shield; a study in satellite-image interpretation: Precambrian Res., v. 16, no. 4, p. A53-A54.

Nagy, R.M., Ghuma, M. and Rogers, J.J.W., 1976. A crustal suture and lineament in North Africa: Tectonophysics, v. 31, no. 3-4, p. T67-T72.

Neary, C.R., 1978. Evolution and mineralisation of the Arabian-Nubian Shield: Mining Mag., v. 143, no. 7, p. 47-48.

Powell, C. McA., 1984. Terminal fold-belt deformation: Relationship of mid-Carboniferous megakinks in the Tasman Fold Belt to coeval thrusts in cratonic Australia: Geology, v. 12, p. 546-549.

Reymer, A.P.S., 1983. Metamorphism and tectonics of a Pan-African terrain in southeastern Sinai: Precambrian Res., v. 19, p. 225-238.

Reymer, A.P.S., 1984. Metamorphism and tectonics of a Pan-African terrain in southeastern Sinai; a reply: Precambrian Res., v. 24, no. 2, p. 189-197.

Sabet, A.H., 1981. Tectonics of the northern Red Sea Hills, Egypt: Proceedings of the International Conference on Basement Tectonics 4, p. 201-208.

Sestini, J., 1965. Cenozoic stratigraphy and depositional history, Red Sea, Sudan: Bull. Am. Assoc. Petro. Geol., v. 49, no. 9, p. 1453-1472.

Shimron, A.E., 1984. Evolution of the Kid Group, southeast Sinai Peninsula: Thrusts, melanges, and implications for accretionary tectonics during the late Proterozoic of the Arabian-Nubian Shield. Geology, v. 12, p. 242-247.

Sillitoe, R.H., 1979. Metallogenic consequences of late Precambrian suturing in Arabia, Egypt, Sudan, and Iran: I.S.G. Bull. no. 3, v. 1, p. 110-120.

Stacey, J.S. and Hedge, C.E., 1984. Geochronologic and isotope evidence for early Proterozoic crust in the eastern Arabian Shield: Geology, v. 12, p. 310-313.

Stern, R.J., Gottfried, David and Hedge, C.E., 1984. Late Precambrian rifting and crustal evolution in the Northeastern Desert of Egypt: Geology, v. 12, p. 168-172.

Stern, R.J., and Hedge, C.E., 1985. Geochronologic and isotopic constraints on late Precambrian crustal evolution in the Eastern Desert of Egypt: Am. Jour. Sci., v. 285, no. 2, p. 97-127.

Stoeser, D.B. and Camp, V.E., 1985. Pan-African microplate accretion of the Arabian Shield: Geol. Soc. Am. Bull., v. 96, p. 817-826.

Stoeser, D.B. and others, 1985. U/Pb zircon geochronology of the southern part of the Nabitah mobile belt and Pan-African continental collision in the Saudi Arabian Shield: U.S. Geol. Surv., Open-File Report, 92 p.

Stoeser, D.B. and Stacey, J.S., 1983. Granitoid plutonic rocks of the Arabian Shield: U.S. Geol. Surv., Prof. Paper 1375, 287 p.

Sturchio, N.C., 1983. Geologic evolution of Precambrian basement of eastern desert of Egypt: AAPG Bulletin, v. 67, no. 3, 554 p.

Sturchio, N.C., Sultan, Mohamed and Batiza, Rodey, 1983. Geology and origin of Meatiq Dome, Egypt: A precambrian metamorphic core complex?: Geology, v. 11, p. 22-76.

Turkistany, A.R.A., 1977-78. Petrography and sequence of granites in the Jabal Sayid Complex, Saudi Arabia: Precambrian Res. v. 5-6.

Vail, J.R., 1977-78. Outline of the geology and mineralization of the Nubian Shield east of the Nile Valley, Sudan: Precambrian Res., v. 5-6.

Vail, J.R., 1978. Outline of the geology and mineral deposits of the Democratic Republic of the Sudan and adjacent areas: Overseas Geol. & Min. Resour. no. 49, 68 p.

Vail, J.R., 1983. Pan-African crustal accretion in North-east Africa: Jour. African Earth Sci., v. 1, no. 3-4, p. 285-294.

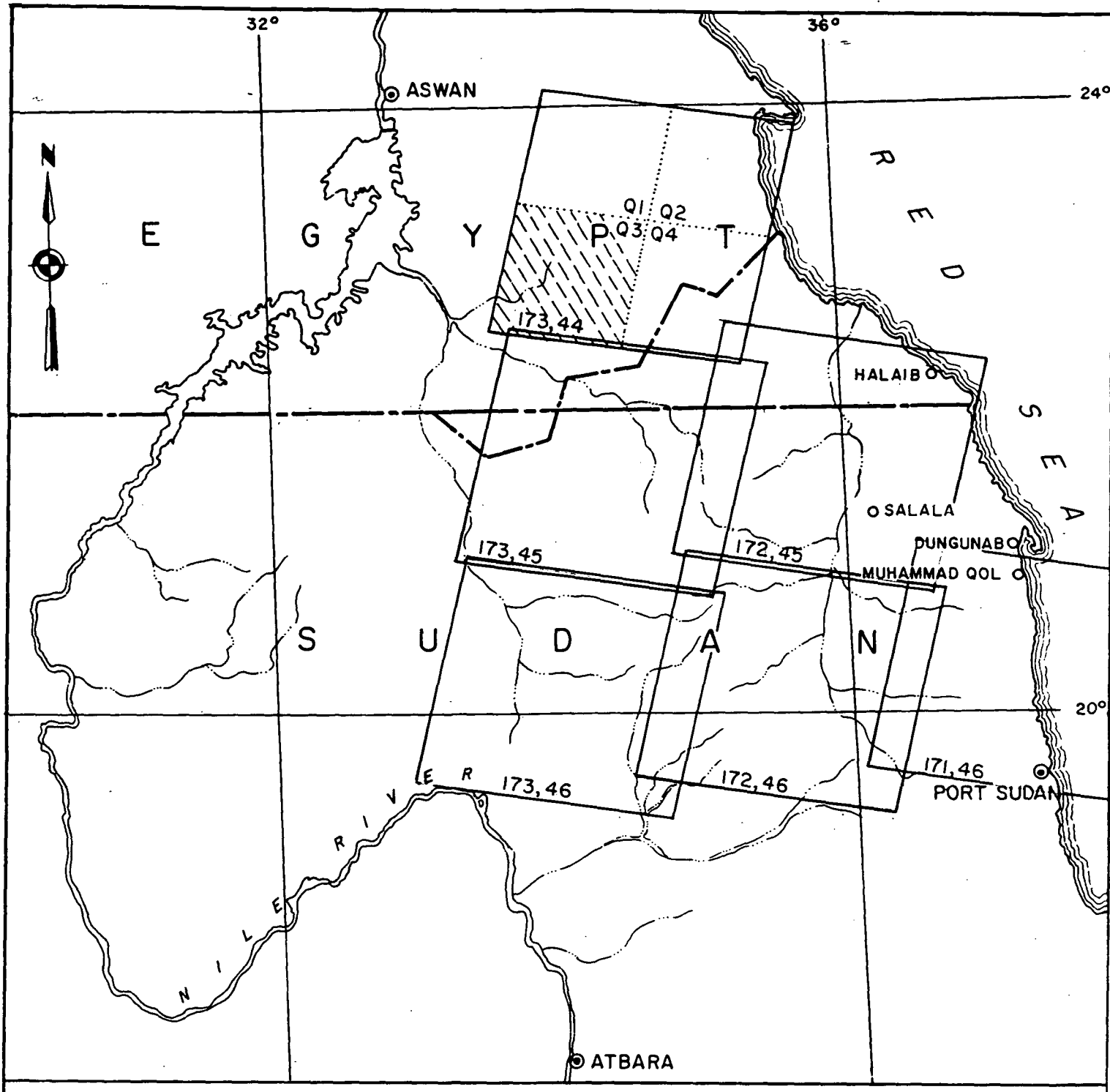
Vail, J.R., 1985. Pan-African (late Precambrian) tectonic terrains and the reconstruction of the Arabian-Nubian Shield: Geology, v. 13, p. 839-842.

Vail, J.R., 1984. The nature of the Basement Complex of the Nubian Shield in North-east Africa: addendum: Jour. African Earth Sci., v. 2, no. 4, p. 389-390.

Warden, A.J., 1982. The northeast branch of the Mozambique Belt: Precambrian Res., v. 16, no. 4, p. A41-A42.

Woodward, L.A., 1984. Basement control of Tertiary intrusions and associated mineral deposits along Tijeras-Canoncito Fault System, New Mexico: Geology, v. 12, p. 531-533.

Figures



0 50 100 150 200 250

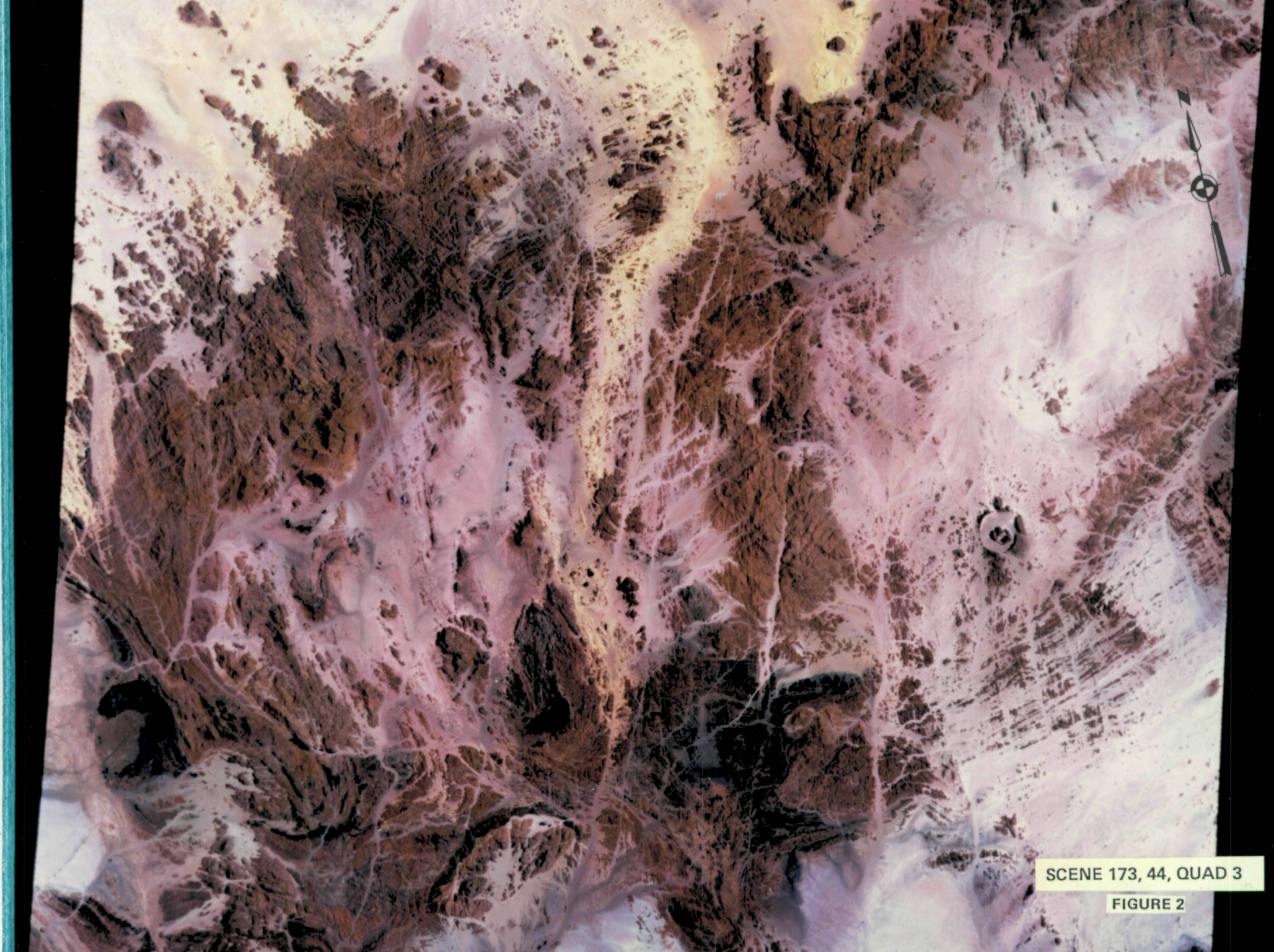
SCALE IN KILOMETERS

BECHTEL
SAN FRANCISCO

RED SEA HILLS

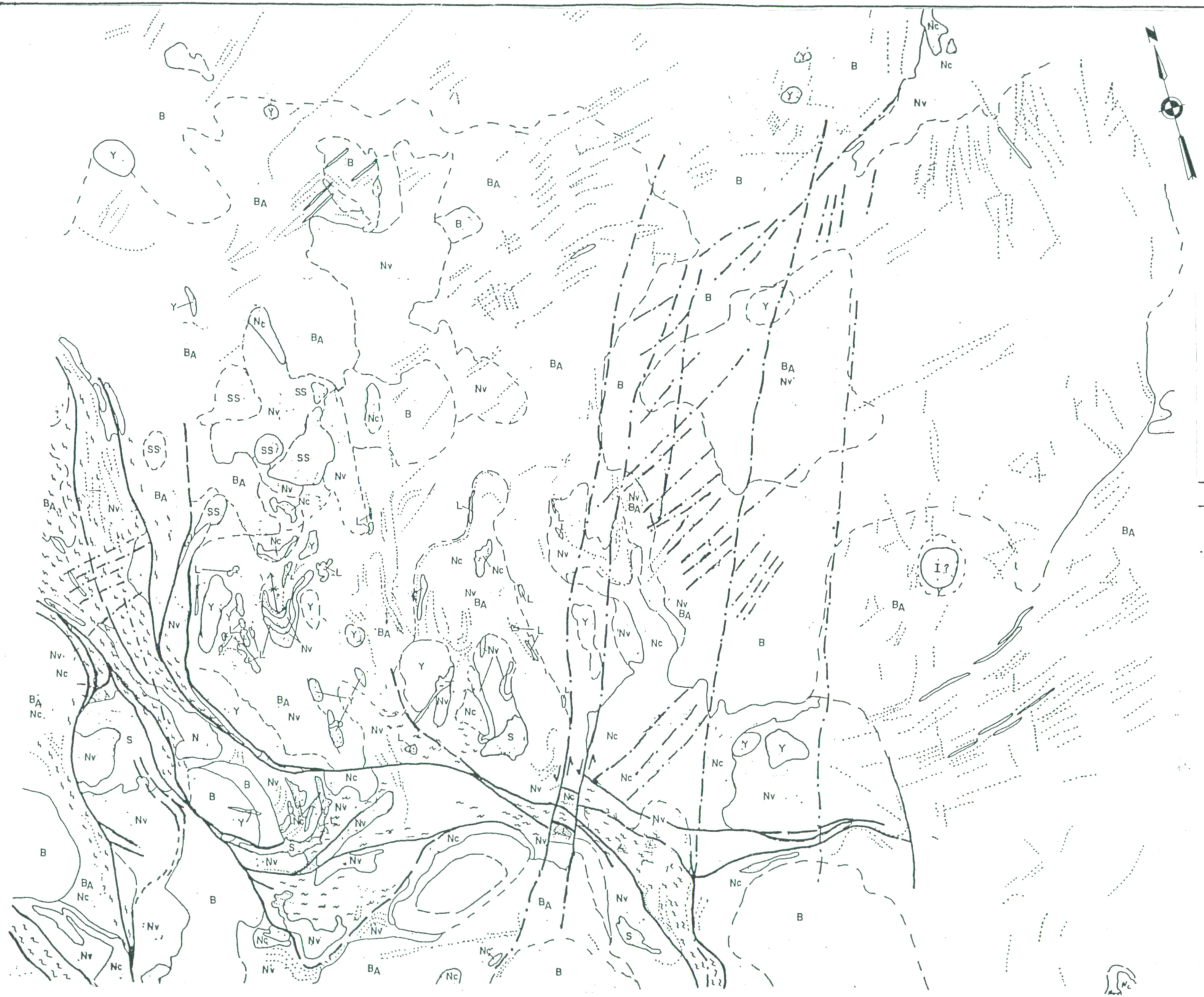
LOCATION MAP
TM LANDSAT SCENES

JOB No.	DRAWING No.	REV.
17835	FIGURE 1	



SCENE 173, 44, QUAD 3

FIGURE 2



BECHTEL
SAN FRANCISCO

RED SEA HILLS

PRELIMINARY GEOLOGY INTERPRETATION
TM LANDSAT SCENE 173-44-Q3

JOB No.	DRAWING No.	REV.
17835	FIGURE 3	

ASTROBLEME(?)
SCENE 173, 44, QUAD 3
FIGURE 4